Kuvshinov Oleg Alexandrovich
Student
Ural Federal University named after first
President of Russia B.N. Yeltsin
Russia, Ekaterinburg
Academic supervisor: Gubina Dilyara Ilshatovna

DEPENDENCE OF RADIATION PATTERN ON THE PARAMETERS OF ANTENNA ARRAY

Abstract. *In this article the influence of different parameters of two and three dimensional antenna array (AA) the Radiation Pattern (RP) is presented. Research method involves the development of software that allows instantly demonstrating the changes of the RP form in accordance with changing of AA parameters. In the conclusion groups of the parameters were obtained that contribute to achieving an effective antenna.*

Keywords: *radiation pattern, beamforming, smart antenna, wireless communication.*

Кувшинов Олег Александрович
Студент
Уральский федеральный университет имени первого
Президента России Б.Н. Ельцина
Россия, г. Екатеринбург
Научный руководитель: Губина Диляра Ильшатовна

ЗАВИСИМОСТЬ ДИАГРАММЫ НАПРАВЛЕННОСТИ ОТ ПАРАМЕТРОВ АНТЕННОЙ РЕШЕТКИ

Аннотация. *В данной статье представлено влияние различных параметров двумерной и трехмерной антенной решетки (АР) на диаграмму направленности (ДН) данной антенны. Для исследования были разработаны два программных продукта для двух- и трехмерной АР соответственно, позволяющих наблюдать в реальном времени изменение формы ДН в соответствии с изменением различных параметров. В результате работы были получены различные наборы параметров, обеспечивающие эффективную конструкцию АР.*

Ключевые слова: *диаграмма направленности, формирование луча, умная антенна, беспроводные технологии.*

1. Introduction

All people use their cell phones every day to communicate with each other but almost no one thinks about processes and actions which happen around them during this time. There is a huge system through the World that provides possibility to get in touch with almost any point on the Earth. Literally, it is a large network of devices that can instantly exchange information between them.

If two phones try to set a contact and they are not also far from each other, it will not be a problem. However, in most situations this distance is quite long – tens, hundreds and thousands kilometers. In this case antennas are used as intermediaries in connecting installing. In addition, the phones usually move in the area until disconnecting happens. Thus, to save power and improve the Quality of Service Smart Antenna technology was created.

Nowadays it is being actively developed in five generation networks that have already worked in some countries. Smart Antenna is usually a linear or rectangular set of radiative antenna elements that are connected to one digital signal processing block. It is such a kind of antennas that is actively used in modern mobile communication networks because of the main feature of these antennas – possibility to change its RP in accordance with the direction from which incident signal arrives. RP is a basic characteristic of any antenna which defines the variation of the power radiated by an antenna as a function of the direction away from the antenna. It has the main lobe where the most power is concentrated and lots of undesired side lobes. Providing with a high directivity is a very difficult task because lots of parameters influence the RP. This work is aimed to research what and how exactly parameters influence it.

In the first part the investigation of two-dimensional AA is presented and according results are made.

In the second part the same performance was applied in case of three-dimensional AA.

In the last part the conclusion of both researches is presented.

2. Two-dimensional radiation pattern

Assume that there are N antenna radiative elements and there are different types of the elements – isotropic and dipole antenna. Thus, RP can be expressed by the following formula:

$$F(\theta) = F_I(\theta) \cdot \frac{sin\left(\frac{N \cdot r \cdot k_1 d}{2}(sin(\theta) - sin(a)\right)}{N \cdot r \cdot sin\left(\frac{k_1 d}{2}(sin(\theta) - sin(a)\right)} \cdot r + $$
$$+F_D(\theta) \cdot \frac{sin\left(\frac{N \cdot (1-r) \cdot k_2 d}{2}(sin(\theta) - sin(a)\right)}{N \cdot (1-r) \cdot sin\left(\frac{k_2 d}{2}(sin(\theta) - sin(a)\right)} \cdot (1-r), \quad (1)$$

where $F_I(\theta) = F_1(\theta) = 1$; $k = \frac{2\pi}{\lambda}$ – wave number, where λ – wavelength of the signal, m; d – distance between the elements, m; a – angle of the arrived signal, degrees; $F_D(\theta) = |sin(\theta)|$; $r = \frac{N_I}{N}$ – part of isotropic elements among all the elements, $r \in [0, 1]$. It is assumed that each type of antenna elements emits wavelengths with its own wavelength – λ_1 and λ_2 for isotropic and dipole elements accordingly.

To analyze the influence of the different parameters on the RP a special program «Radiation Pattern» was developed. The main window is presented in Fig. 1.

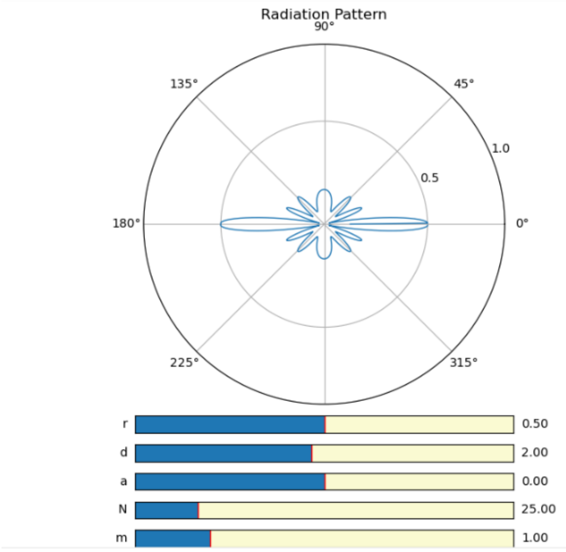

Fig. 1 – The main window of the program «Radiation Pattern».

This instrument allows changing the parameters and watching how the RP is acting in real time. The following parameters can be changed:

1. $r = \frac{N_I}{N}$;
2. $d^{`} = \frac{\frac{1}{2} \cdot (\lambda_1 + \lambda_2)}{d}$;
3. a;
4. N;
5. $m = \frac{\lambda_2}{\lambda_1}$.

The opposite lobe is just a result of mathematical modeling and in reality it does not exist because an antenna cannot emit in the opposite direction.

During the research the following results were obtained:

1. Increasing of the number N makes the main lobe thinner but the size of the antenna is expanding significantly.
2. If the distance between the elements is quite low, then lots of undesired maximums appear. If the distance is wide enough, then the main lobe is thick. The optimum value is half of the arithmetic mean wavelengths.

3. Combining different values of the frequencies and distance d, it is possible to achieve the maximization of an antenna parameters. In the table 1 some useful combinations are presented.

Table 1. The combinations of antenna parameters which lead to optimum result

d`	m
2	1
3,25	2
4	4
0,75	0,25

4. The dipole elements contribute to reduction of the main lobe level in range of small angles but in the area of large angles this value is high enough.

5. The correct choice of amount of each type of elements contributes to receive a better and more suitable RP [1–4].

3. Three-dimensional radiation pattern

The main window of the program for three-dimensional RP is in Fig. 2.

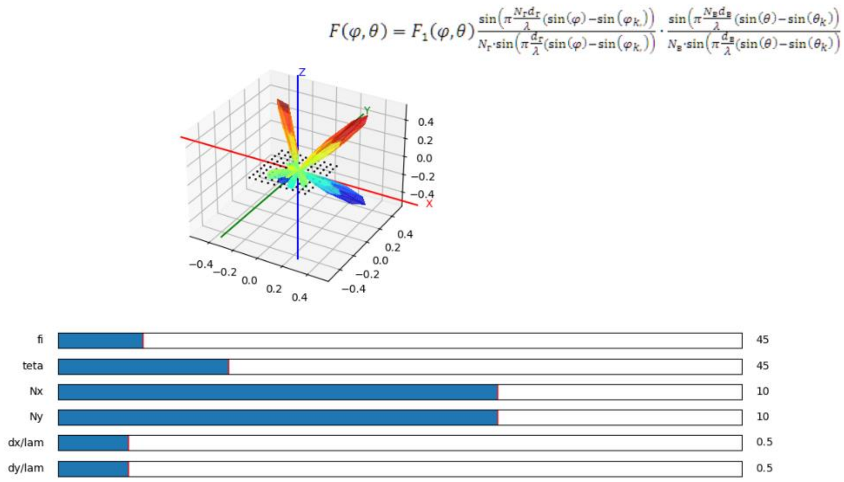

Fig. 2 – The main window of the program.

Black dots denote the elements of antenna array and in case of changing the parameters theirs position is changed too. Red parts of RP mean the highest power and blue areas the lowest power. In the top right corner we can see the formula through which the RP is calculated and this formula is

$$F(\varphi,\theta) = F_1(\varphi,\theta)\frac{\sin\left(\pi\frac{N_x d_x}{\lambda}\left(\sin(\varphi)-\sin\left(\varphi_{k,}\right)\right)\right)}{N_x\cdot\sin\left(\pi\frac{d_x}{\lambda}\left(\sin(\varphi)-\sin\left(\varphi_{k,}\right)\right)\right)}\cdot$$

$$\cdot\frac{\sin\left(\pi\frac{N_y d_y}{\lambda}\left(\sin(\theta)-\sin(\theta_k)\right)\right)}{N_y\cdot\sin\left(\pi\frac{d_y}{\lambda}\left(\sin(\theta)-\sin(\theta_k)\right)\right)}, \tag{2}$$

where $F_1(\varphi,\theta) = |\sin(\varphi)|$ – RP of each element that is a dipole antenna; $\varphi_{k,}$ and θ_k – azimuth and elevation angles at which the signal is impinged, degrees.

During the research the following results were obtained:

1. The value of the azimuth does not influence the antenna RP parameters at all.

2. The minimal value of elevation angle at which the antenna can provide with directivity is equal to 10 degrees. If the value is less (e.g. 3 degrees) the antenna cannot create a main lobe in according direction.

3. Than less the number of elements in X direction, than thicker the main lobe in X0Y projection. Such decline can be corrected by increasing the distance between the elements as the same times n as the number of elements was decreased.

4. If the number of the elements in Y direction is reduced the main lobe is becoming thicker in X0Y projection. In this case the increasing the distance between the elements in considered direction does not lead to the desired result.

5. The distance between the elements as ratio to a wavelength in the same direction can be increased from 0,5 to 1. This rule works properly until n is equal to 5. In case of higher values a back lobe appears in the opposite direction towards the ground.

6. By increasing the number of the elements in each direction the width of the main beam is becoming lower. However, if the number of the elements is already equal to 10, the next increment is not so significant. The optimal value of the number of the elements is $N_x = N_y = 8$.

7. To make the whole antenna smaller the distance between the elements in both directions can be reduced to the 0.3 value as ratio to a wavelength. The increasing

the distance from the optimal value 0.5 allows appearing lots of non-directional parasitic lobes [5–8].

In table 2 the optimum combinations of the described parameters are presented.

Table 2. Optimum variants of AA structure

Number of antenna elements in each direction	The whole number	Minimum distance between the elements, cm	The whole size in case of 3 GHz signal, cm
8	64	5	90 x 90
10	100	3	80 x 80

4. Conclusion

The influence of different Smart Antenna parameters on the RP of linear and rectangular antenna arrays was explored. The results of the experiments can help design an antenna that involves high directivity and reasonable cost.

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